

# Medial transposition of a split lateral rectus muscle for complete oculomotor nerve palsy

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| <b>PURPOSE</b>     | To evaluate the effect on ocular alignment of Y splitting the lateral rectus muscle and then reattaching the 2 ends near the medial rectus muscle insertion in patients with complete oculomotor nerve palsy.  |
| <b>METHODS</b>     | All eyes with oculomotor nerve palsy treated between May 2008 and February 2010 with Y splitting and transposition of the lateral rectus muscle to the medial rectus muscle were prospectively studied. In this procedure, the lateral rectus muscle was split: the upper half was transposed to the superior border and the lower half to the inferior border of the medial rectus insertion. For the muscles that had lost the ability to stretch and strain due to fibrosis, a hang-back technique was used. In some patients, the medial rectus muscle of the same eye was subsequently strengthened or the lateral rectus muscle of the fellow eye was recessed. Final deviation from 0 $^{\Delta}$ to 10 $^{\Delta}$ was considered a successful result. |
| <b>RESULTS</b>     | A total of 10 patients were included. Patients had a preoperative horizontal deviation >45 $^{\Delta}$ (range, 45 $^{\Delta}$ -90 $^{\Delta}$ ). Of the 10 patients, 5 attained stable results following surgery, and 5 with postoperative undercorrection between 20 $^{\Delta}$ and 30 $^{\Delta}$ required further surgeries. Postoperatively, 2 patients improved their sensorial status in a very limited range of gaze and 2 patients had symptomatic diplopia.  |
| <b>CONCLUSIONS</b> | Acceptable aesthetic results can be achieved in the treatment of complete oculomotor nerve palsy with the transposition of the split lateral rectus muscle to the medial rectus muscle area. (J AAPOS 2013;17:402-410)   |

In total oculomotor nerve paralysis, the function of four of the six extraocular muscles is compromised, leaving the lateral rectus and superior oblique muscles unopposed. As a result, in the primary position, the affected eye is aligned in an abducted position, with slight depression and intorsion. In many cases, concurrent paralysis of the levator palpebra causes ptosis in the same eye.<sup>1,2</sup> In such cases, existing therapeutic options are limited. The goal of surgery is to achieve orthotropia in the primary position with an enlarged binocular visual field away from primary position, even if full restoration of adduction, elevation, or depression is not achieved. Conventional super-maximum recession-resection procedures cannot achieve this goal,<sup>2,3</sup> and a number of alternative procedures have been proposed: transposition of the superior oblique 1–3.5 mm anteriorly to the medial insertion of the superior rectus muscle with a large recession of the lateral rectus muscle<sup>4-7</sup>; use of a temporal mattress suture<sup>8</sup>; insertion of an eye muscle prosthesis<sup>9</sup>; fixation of the eye with fascia lata<sup>10</sup>; fixation of the

globe to the periosteum of the medial orbital wall or medial canthal ligament<sup>11-13</sup>; medial transposition of the lateral rectus muscle<sup>14</sup>; and medial transposition of the lateral rectus muscle with the splitting and reattachment of this muscle near the vortex veins.<sup>15</sup> Most of these procedures require surgery on at least 2 muscles and long-term orthotropia in the primary position is variably successful.<sup>4-15</sup> The purpose of this study was to prospectively evaluate, in patients with complete oculomotor nerve palsy, the outcomes of treatment with a modification of a surgical technique developed by Kaufmann<sup>15</sup> in which the lateral rectus muscle undergoes Y splitting and the ends are transposed to the medial rectus area preequatorially. In Gokyigit's modification of the technique, the upper half of the split lateral rectus muscle is passed under the superior rectus–superior oblique complex and the lower half is passed under the inferior rectus and inferior oblique muscles. The split ends are reattached 1 mm posterior to the superior and inferior borders of the medial rectus muscle insertion.

## Subjects and Methods

This was a single-center, prospective, consecutive cohort study. Approval was obtained from the Ethics Committee and the Institutional Review Board of the Prof Dr N Reşat Belger Beyoglu Education and Research Eye Hospital, Istanbul. The study and data collection conformed to all local laws and were compliant with the principles of the Declaration of Helsinki. Informed consent was

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obtained from each participant or from 1 or both parents of participants <18 years of age. All patients were informed prior to the surgery that their ocular alignment can be improved only in the primary position.

All patients underwent transposition of the Y-split lateral rectus muscle to the medial rectus muscle area for treatment of chronic complete oculomotor nerve palsy. All procedures were performed at the Prof Dr N Reşat Belger Beyoglu Education and Research Eye Hospital, Istanbul, between May 2008 and February 2010. Inclusion criteria were complete chronic oculomotor nerve palsy with a stable ocular deviation angle for at least three consecutive visits and a period of at least 6 months between the onset of palsy and the operation. Patients who met any of the following criteria were excluded: incomplete oculomotor nerve palsy; mechanical causes for limited elevation, depression, or adduction of the eye, such as fibrosis, high myopia (heavy eye or divergent strabismus fixus), myositis, endocrine orbitopathy, blowout fracture of the orbital floor, fracture of the medial orbital wall, or muscle entrapment, and other causes of limited ocular movements, such as Duane retraction syndrome or misinnervation; ocular myasthenia gravis and chronic progressive external ophthalmoplegia; history of previous extraocular muscle surgery; and any other associated ocular pathology that interfered with adequate examination.

Before surgery, all patients underwent a complete ophthalmological examination, including evaluation of their best-corrected visual acuity, slit-lamp biomicroscopy, refraction, and fundus examination. The ocular deviation was measured at a distance and near in the primary position and in the diagnostic position of gaze with either eye fixing using objective methods, such as cover testing, alternate cover testing, prism cover testing, and the Krimsky and Hirschberg corneal reflection tests for patients who with a blind or deeply amblyopic eye (visual acuity of  $\leq 0.1$ ) with or without eccentric fixation, or using subjective methods, such as the red glass test and the Lee's screen test, which are based on diplopia fields. The Krimsky and Hirschberg tests are also indicated for patients with severe limitation in ocular rotations, as seen in patients with paralytic strabismus.

Ocular ductions and versions were evaluated pre- and postoperatively. The forced-duction test<sup>2,16</sup> and the active force generation test<sup>2,13</sup> were performed in all cases preoperatively. Ductions, versions, and forced ductions were evaluated with a 6-point scale from 0 to -5, with 0 indicating full movement in both eyes; -4, inability to move the affected eye past the midline; and -5, inability to move the affected eye to the midline.<sup>17-20</sup> A negative active force generation test on the medial rectus muscle was taken as an indication for transposition surgery.

Binocular function was assessed with spectacle correction in place. The Worth 4-dot test (Richmond Products Inc, Albuquerque, NM) was administered at 6 m and at 1/3 m. The presence or absence of diplopia was documented using red-green filters and the Worth 4-dot test. Stereoacuity was measured with the Titmus stereoacuity test (Optical Co Inc, Chicago, IL) at 1/3 m.

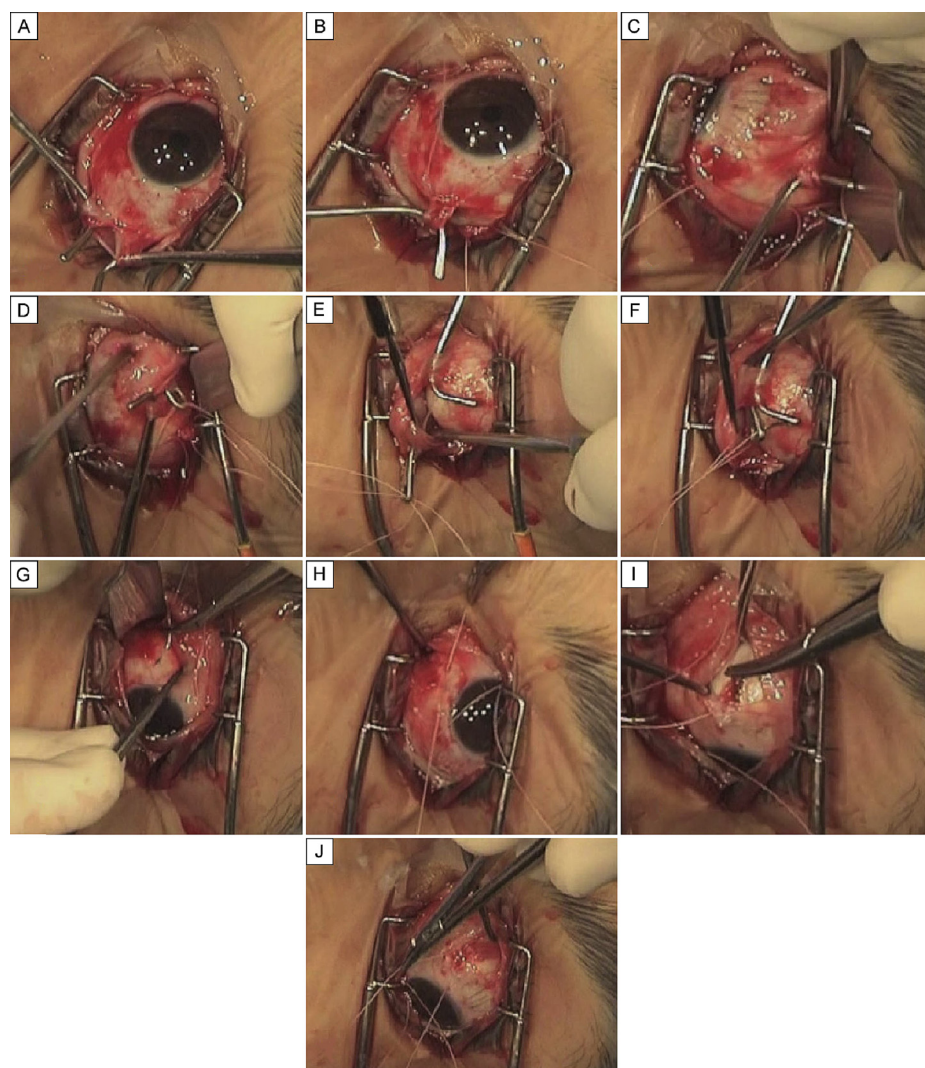
A diagnosis of complete oculomotor nerve palsy was made in the presence of defective adduction (-4) of the eye; defective vertical movements of the superior rectus, inferior rectus, or inferior oblique muscles; a dilated pupil that did not respond to light; and ptosis.

The surgical procedure was identical in all patients, who were operated on by the same surgeon (BG) under general anesthesia. A 300° conjunctival limbal peritomy was made from the 4 o'clock to the 2 o'clock meridian in the right eye and from the 10 o'clock to the 8 o'clock meridian in the left eye. The lateral rectus muscle was cleared of adherent tissues; the intermuscular membranes attached to the borders of the muscle were cut for a distance of 15 mm posterior to the insertion. The muscle was split at up to 15 mm toward the posterior septum without damage to the septum or the pulley structure (Figure 1A). Creating a slit in the posterior portion of the Tenon's sleeve can enhance the effect of our procedure. A slit seems to prevent serious undercorrection without necessity of secondary procedure on the ipsilateral medial rectus muscle. One or two full-thickness locking bites were placed at the edge of the muscle halves (1- or 2-point fixation). We used nonabsorbable 6-0 polyester sutures (Dacron; Ethicon Inc, Somerville, NJ) to secure muscle. The muscle halves were disinserted (Figure 1B), and the sutures on the muscle halves were passed through the hole of the Gass hook (Katena, Denville, NJ). Then the upper half of the muscle was passed under the superior oblique tendon behind the insertion with the help of the Gass hook (Figure 1C and D) and the inferior half of the muscle was passed between the sclera and both the inferior rectus and inferior oblique muscles (Figure 1E and F).

The two halves of the lateral rectus muscle were pushed far posteriorly so that they could be transposed closer to the insertion of the medial rectus muscle. In this intraoperative maneuver, we rotated the globe medially by grasping the lateral rectus insertional stump (where a small tendon remained) with two locked teeth forceps to facilitate reinsertion of the lateral muscle halves in their new position. These two halves were advanced anteriorly to the medial rectus muscle insertion. This maneuver was performed to ensure tightening of the sutures and to prevent the tearing of the scleral bite area from the tension. The lower half of the lateral rectus muscle was reattached 1 mm posterior to the inferior border of the medial rectus insertion (Figure 1G and H) and the upper was reattached 1 mm posterior to the superior border of the medial rectus insertion (Figure 1I and J). The postoperative muscle positions above and below the globe are shown in Figure 2A and B.

Immediately following reattachment, the position of the two eyes was evaluated using the Hirschberg test. The desired alignment was orthotropia or slight esodeviation in the primary position. If there was significant esotropia or exotropia an adjustment was made to correct for this by either loosening or tightening the lateral rectus muscle halves. We adjusted the position of the eye aiming for slight esotropia. If an adjustment was needed because of the overcorrection or undercorrection, we adjusted both arms; however, if we noted an up- or downshift without excessive overcorrection, we only adjusted the necessary muscle arm. The forced duction test under anesthesia was applied only to detect any tissue interruption.

If any vertical deviation was noted after the transposition, we released the suture slightly on the superior side if high and inferior side if low and tightened the opposite one to eliminate the deviation. In our first 2 cases, the lateral rectus muscle had severe fibrosis, and two different 6-0 nonabsorbable sutures could



**FIG 1.** Y splitting and transposition of the lateral rectus muscle to the medial rectus muscle area. A, The lateral rectus muscle is split into two approximately equal parts. B, The superior half of the lateral rectus muscle is released from the insertion with suture and two 5-0 polyester sutures are placed on both sides of the inferior half of the lateral rectus muscle. C, The superior rectus and superior oblique muscle are isolated. D, The sutures on the superior half of the muscle are passed through the hole of the Gass hook. The upper half of the muscle is passed under the superior rectus muscle and the superior oblique complex behind the superior oblique tendon insertion. E, The inferior half of the muscle is passed under the inferior oblique muscle. F, The inferior half of the muscle was passed under the inferior rectus muscle. G, Lower half suturing to the sclera 1 mm posterior to the inferior border of the medial rectus insertion. H, The inferior half was fixed to the new insertion. I, Upper half suturing to the sclera 1 mm posterior to the superior border of the medial rectus insertion. J, The upper half is fixed to the new insertion.

not be placed securely in half of the muscle. For this reason, we collapsed the half of the muscle tendon with only one bite for 1 suture. Otherwise, in patients who had healthy tendons with sufficient muscle width, the halves were reinserted with two scleral bites parallel to the limbus. Most cases had tight and short conjunctival tissue on the lateral rectus area because of the long-term, large-angle exotropia. We left the sclera without conjunctiva if the conjunctiva was short and tight.

In 4 cases (cases 3, 4, 6, and 8), a second operation was performed 2-6 weeks after the first. These included medial rectus resection<sup>21</sup> (case 3) and medial rectus tucking<sup>22</sup> (cases 6 and 8). Case 4 had bilateral oculomotor nerve palsy that was complete only in the right eye; thus we performed a extra-large recession of the lateral rectus muscle (12 mm) in the left eye in this case.<sup>13</sup> All cases were consulted with oculoplastic surgery depart-

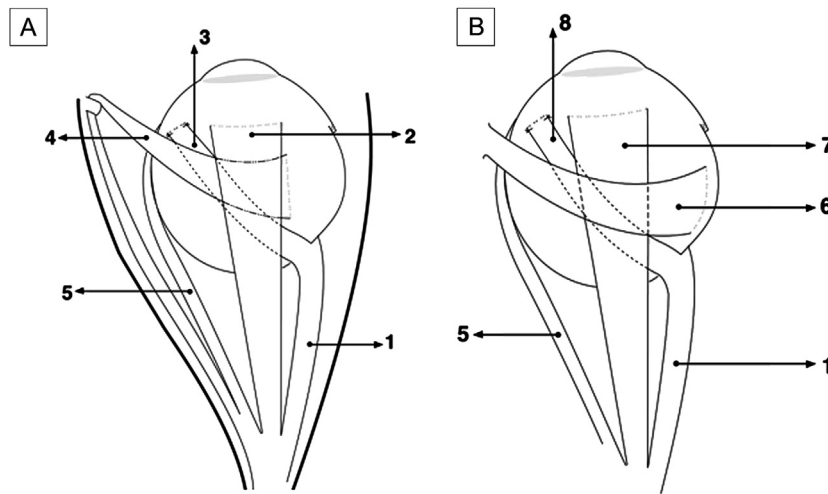
ment for their ptosis. Some patients underwent ptosis surgery after their strabismus surgery.

All examinations were repeated at postoperative week 1, month 1, month 3, month 6, and month 12 and annually thereafter. After the Y splitting transposition of the lateral rectus muscle, an ocular deviation within 10<sup>Δ</sup> (5° Hirschberg) of orthotropia in primary position was considered a successful result.

Statistical analyses were performed with SPSS for Windows, version 16 (SPSS Inc, Chicago, IL). A paired samples *t* test was used for variables and *P* < 0.05 was considered statistically significant.

## Results

The study population consisted of 12 eyes of 10 patients (6 males) with a mean age of 31.7 years (range, 6-66 years).



**FIG 2.** Postoperative muscle positions view. A, Above the globe. B, Below the globe. 1, Lateral rectus muscle; 2, Superior rectus muscle; 3, Superior half of the lateral rectus muscle; 4, Superior oblique tendon; 5, Medial rectus muscle; 6, Inferior oblique muscle; 7, Inferior rectus muscle; 8, Inferior half of the lateral rectus muscle.

The patients' demographic data, etiology of paralysis, pre- and postoperative horizontal deviations, ocular ductions, outcomes of preoperative forced duction and force generation tests and pre- and postoperative sensorial status, outcomes of secondary surgery, final horizontal alignment and follow-up are summarized in [Tables 1 and 2](#).

Preoperative horizontal deviation in primary position of gaze was  $73.7^{\Delta} \pm 8.9^{\Delta}$ . After the first operation, the mean horizontal ocular deviation was  $11.8^{\Delta} \pm 1.0^{\Delta}$  and the differences between the pre- and postoperative horizontal deviations were statistically significant ( $P < 0.001$ ). In first week after surgery, 7 patients had successful results. In 2 cases (cases 3 and 4), we applied hang-back suturing not exceeding 5.5 mm (mean, 5.1 mm). In these 2 patients, whose lateral rectus muscles were seriously fibrotic, the postoperative success diminished during the first 2 postoperative months. In case 3, we observed that the transposed muscles remained in the desired position during the operation. In the second months after the Y splitting transposition of the lateral rectus muscle, 5 of the 10 patients attained stable results ( $0^{\Delta}$ - $10^{\Delta}$ ) postoperatively and 5 had between  $20^{\Delta}$  and  $30^{\Delta}$  undercorrection. None of the patients was overcorrected for the follow-up period.

Additional muscle surgery was performed in 4 of the 10 cases. Procedures included medial rectus resection (1 case), medial rectus tucking (2 cases), and lateral rectus recession to the other eye (1 case). On the final postoperative visit, the mean horizontal ocular deviation was  $8.5^{\Delta} \pm 1.3^{\Delta}$  and 9 patients had successful results ([Table 2](#)).

After surgery, there was no significant improvement in the adduction ( $P = 0.47$ ), depression ( $P = 0.66$ ), or elevation ( $P = 0.53$ ) of the affected eyes; however, there was a significant reduction in abduction ( $P < 0.001$ ). Two patients had lateral rectus restriction ( $-3$ ), as evidenced by positive passive forced duction testing to adduction.

No patient had postoperative anomalous head postures for fusion and none of the 10 patients demonstrated a fusion response at 6 meters. No patient demonstrated stereoacuity  $>100$  arcsec following the first operation. Of the 10 patients, 4 had measurable stereoacuity (3000 arcsec) in a very limited range of gaze with (cases 4 and 6) or without (cases 7 and 9) prisms ([Tables 1 and 2](#)).

There were no intraoperative complications, such as orbital hemorrhage (damage of vortex veins) or globe perforation, or postoperative complications or complaints. We did not observe any patients who had serious retinal detachment, unusual inflammation, or any signs of optic nerve compression during follow-up. None of the patients were overcorrected. Following strabismus surgery, 6 of the 10 cases underwent ptosis surgery, all with successful results. [Figure 3](#) shows the pre- and postoperative photographs of a patient with right oculomotor nerve palsy (case 10).

## Discussion

The surgical management of exotropia from complete oculomotor nerve palsy presents a significant challenge, and existing therapies are limited due to loss of extraocular muscle function.<sup>13</sup> [Table 3](#) provides an overall comparison of studies that have used various procedures.<sup>7,10,12-15,23-28</sup> Anchoring the eye medially using an orbital fascia or fascia lata graft has been effective, but this surgical technique is difficult and highly invasive.<sup>10,24,25,29</sup> The other limitations of these methods are the need for complex calculations to select the optimal band measurement, the introduction of a foreign body into the orbit, the fact that it may not be useful in small children whose orbits are still growing, the long length of the operation, and the need for additional extraocular muscle surgery.<sup>24,25,29</sup>

In 1991 Kauffmann<sup>15</sup> introduced lateral rectus muscle splitting for complete oculomotor palsy, describing 2



Table 1. Summary of patient demographic data, etiology of paralysis, preoperative deviations, restriction of ocular movement, and sensorial status

| No.            | Age, years/sex | Laterality | BCVA  |        | Etiology   | Pre-op horizontal deviation, PD | Pre-op ocular ductions <sup>a</sup> |       | Pre-op forced duction |     | Pre-op force generation | Pre-op sensorial status <sup>b</sup> |         |          |
|----------------|----------------|------------|-------|--------|------------|---------------------------------|-------------------------------------|-------|-----------------------|-----|-------------------------|--------------------------------------|---------|----------|
|                |                |            | Right | Left   |            |                                 | Abd                                 | Add   | Abd                   | Add |                         | Fusion <sup>c</sup>                  | Supress | Diplopia |
| 1              | 6/M            | L          | 20/20 | 20/200 | Congenital | 60                              | 0                                   | -5    | Neg                   | Neg | Neg                     | NC                                   | NC      | NC       |
| 2              | 42/F           | L          | 20/25 | 20/100 | Trauma     | 52                              | 0                                   | -4    | Neg                   | Neg | Neg                     | —                                    | Yes     | —        |
| 3              | 54/M           | R          | NLP   | 20/20  | Trauma     | 90                              | 0                                   | -5    | Neg                   | -4  | Neg                     | NC                                   | NC      | NC       |
| 4 <sup>d</sup> | 26/M           | R          | 20/70 | 20/20  | Trauma     | 90                              | 0                                   | -5    | Neg                   | -4  | Neg                     | Yes                                  | —       | Yes      |
| 5              | 66/M           | R          | 20/25 | 20/25  | Trauma     | 90                              | 0                                   | -4    | Neg                   | Neg | Neg                     | NC                                   | NC      | NC       |
| 6              | 39/M           | Bil        | 20/20 | 20/25  | Unknown    | 90                              | 0                                   | -4/-4 | Neg                   | Neg | Neg                     | Yes                                  | —       | Yes      |
| 7              | 25/M           | Bil        | 20/25 | 20/20  | Infection  | 70                              | 0                                   | -5/-4 | Neg                   | Neg | Neg                     | Yes                                  | —       | Yes      |
| 8              | 25/F           | L          | 20/20 | 3/200  | Trauma     | 60                              | 0                                   | -5    | Neg                   | Neg | Neg                     | —                                    | Yes     | —        |
| 9              | 25/F           | L          | 20/20 | 20/20  | Iatrogenic | 90                              | 0                                   | -4    | Neg                   | Neg | Neg                     | Yes                                  | —       | Yes      |
| 10             | 9/F            | R          | 5/200 | 20/20  | Congenital | 45                              | 0                                   | -4    | Neg                   | Neg | Neg                     | —                                    | Yes     | —        |

Abd, abduction; Add, adduction; Bil, bilateral; BCVA, best-corrected Snellen visual acuity; NC, noncooperating; NLP, no light perception; PD, prism diopters.

<sup>a</sup>Preoperative abduction, adduction of paralytic eye.

<sup>b</sup>Worth 4 dot test; none of the patients were adaptive preoperatively.

<sup>c</sup>Four patients had fusion in 33 cm with prism.

<sup>d</sup>Case 4 had bilateral CN 3 palsy but only right eye had complete palsy.

Table 2. Results of primary and secondary operations in patients with complete third cranial nerve palsy

|                |         | Primary operation                |          |                                      |       |                          |          |          |                         | Secondary operation |                                  |                                |                   |
|----------------|---------|----------------------------------|----------|--------------------------------------|-------|--------------------------|----------|----------|-------------------------|---------------------|----------------------------------|--------------------------------|-------------------|
|                |         | Post-op horizontal alignment, PD |          | Post-op ocular ductions <sup>a</sup> |       | Post-op sensorial status |          |          |                         |                     |                                  |                                |                   |
|                |         |                                  |          |                                      |       | Worth 4-dot test         |          |          |                         |                     |                                  |                                |                   |
| No.            | Surgery | 1 week                           | 2 months | Abd                                  | Add   | Fusion <sup>b</sup>      | Suppress | Diplopia | Stereopsis <sup>c</sup> | Surgery             | Post-op horizontal alignment, PD | Final horizontal alignment, PD | Follow-up, months |
| 1              | L LRT   | Ortho                            | Ortho    | −3                                   | −4    | NC                       | NC       | NC       | NC                      | —                   | —                                | Ortho                          | 20                |
| 2              | L LRT   | 10                               | 10       | −4                                   | −4    | —                        | Yes      | —        | —                       | —                   | —                                | 10                             | 16                |
| 3              | R LRT   | 5                                | 25       | −4                                   | −4    | NC                       | NC       | NC       | NC                      | RMR res             | 6                                | 6                              | 18                |
| 4 <sup>d</sup> | R LRT   | 8                                | 30       | −4                                   | −4    | Yes                      | —        | Yes      | Yes                     | LLR rec             | 8                                | 8                              | 26                |
| 5              | R LRT   | 25                               | 25       | −3                                   | −4    | NC                       | NC       | NC       | NC                      | —                   | —                                | 25                             | 4                 |
| 6              | Bil LRT | 30                               | 30       | −4/−4                                | −4/−4 | Yes                      | —        | Yes      | Yes                     | LMR tuck            | 6                                | 6                              | 24                |
| 7              | Bil LRT | 10                               | 10       | −4/−3                                | −4/−4 | Yes                      | —        | —        | Yes                     | —                   | —                                | 10                             | 12                |
| 8              | L LRT   | 20                               | 20       | −4                                   | −4    | —                        | Yes      | —        | —                       | LMR tuck            | 10                               | 10                             | 16                |
| 9              | L LRT   | 10                               | 10       | −4                                   | −4    | Yes                      | —        | —        | Yes                     | —                   | —                                | Ortho                          | 2                 |
| 10             | R LRT   | Ortho                            | Ortho    | −4                                   | −4    | —                        | Yes      | —        | —                       | —                   | —                                | Ortho                          | 12                |

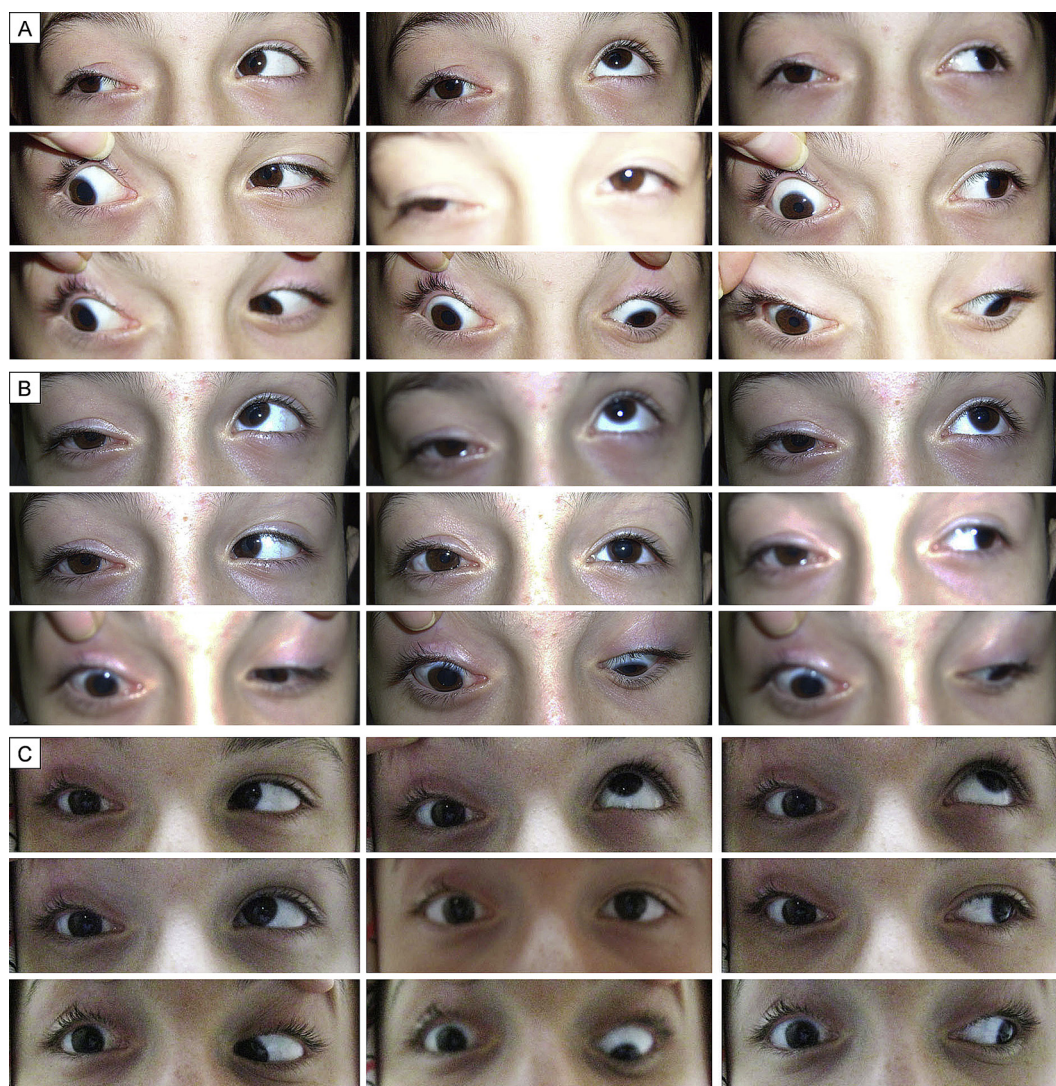
Abd, abduction; Add, adduction; Bil, bilateral; LR, lateral rectus muscle; LRT, Y splitting transposition of lateral rectus muscle; MR, medial rectus muscle; NC, noncooperating; Rec, recession; Res, resection; Stereop, stereopsis.

<sup>a</sup>Postoperative abduction and adduction of paralytic eye.

<sup>b</sup>Cases 4 and 6 had fusion at 30 cm with prisms postoperatively.

<sup>c</sup>Patients with measurable stereoacuity (3000 arcsec).

<sup>d</sup>Case 4 had bilateral oculomotor nerve palsy but only the right eye had complete palsy.



**FIG 3.** Pre- and postoperative photographs of a patient with right oculomotor nerve palsy (case 10). A, Before transposition surgery. B, At 1 month after surgery. C, At 12 months after surgery. Preoperative  $45^{\Delta}$  right exotropia was improved to orthotropia after surgery. The ocular movements, including adduction, elevation, and depression remained restricted; restriction of abduction was  $-4$ .

cases with total third and fourth nerve palsy. He split the lateral rectus muscle and transposed its upper and lower halves to the retroequatorial point, 20 mm from the limbus, near the nasal superior and inferior vortex veins. During the transposition procedure, he passed the upper half of the lateral rectus muscle under the superior rectus muscle and the lower half of the lateral rectus muscle under the inferior rectus muscles. In his first case, he performed 10 mm recession to the lateral rectus muscle as a first operation on affected eye. Three months later, he performed split lateral rectus transposition procedure on the same muscle using an additional fascia lata band fragment for reaching and attaching the muscle to the new fixation point. He only used a suture for fixation in his second case. His procedure resulted in a reduction of  $15^{\circ}$ - $20^{\circ}$  in deviation and  $15^{\circ}$  in head position. However, postoperatively,  $10^{\circ}$  and  $15^{\circ}$  deviations remain, respectively in the

2 cases. Head positions of  $10^{\circ}$ - $20^{\circ}$  also persisted. In the second case postoperative gains were found to be better than the first case. Following the operations, in spite of the remaining deviations, both cases were pleased with their final status.<sup>15</sup>

The modified procedure used in the 10 cases in our study achieved more successful outcomes than Kauffman.<sup>15</sup> Of the 10 patients, 5 attained stable results and 5 had undercorrection between  $20^{\Delta}$  and  $30^{\Delta}$ . This second group required additional surgeries that resulted in successful outcomes. At 15 months' follow-up, these gains persisted. In 1 patient, an additional muscle procedure on the fellow eye was performed, and another was satisfied with a result of  $25^{\Delta}$  and declined follow-up surgery. On the final postoperative visit, 9 of 10 patients had achieved successful results. Like other procedures, this surgery achieved alignment in the primary position but

Table 3. Comparison of the outcomes of studies with various procedures for the treatment of complete oculomotor nerve palsy

| Study                            | No. cases | Method   | Improvement in deviation |                  |   | No. success <sup>a</sup><br>(%) | No. resid<br>exo (%) | No. sec<br>eso (%) | Reoperations<br>(No.)                                | No. final<br>success (%) | Comp   | Follow-up,<br>months |
|----------------------------------|-----------|--|--------------------------|------------------|---|---------------------------------|----------------------|--------------------|--|--------------------------|--|----------------------|
|                                  |           |  | Horizontal               | Vertical         | Ocular ductions   |                                 |                      |                    |  |                          |  |                      |
| Present study                    | 10        | LR Y split trans to MR insertion   | 55.9 <sup>Δ</sup>        | 3.7 <sup>Δ</sup> | Limited abd<br>No change of add, dep, elev              | 5 (50)                          | 5 (50)               | 0                  | MR res or plication (3);<br>LR rec fellow eye (1)    | 9 (90)                   | None   | 15                   |
| Kaufmann et al <sup>15</sup>     | 2         | LR Y split trans to vortex vein area   | 15°-20°                  | —                | —   | 0                               | 2 (100)              | 0                  | —  | 0 (0)                    | None   | —                    |
| Taylor et al <sup>23,b</sup>     | 1         | Medial trans of LR   | 25°                      | 5°               | 5 add, limited abd                                      | 0                               | 1                    | 0                  | MR res and R rec and medial trans                    | 1                        | None   | —                    |
| Morad et al <sup>14</sup>        | 1         | Medial trans of LR and SO tenectomy and MR res                                   | 70 <sup>Δ</sup>          | —                | No change of abd, add, dep, elev                        | 1                               | 0                    | 0                  | —  | 1                        | None   | 12                   |
| Solares et al <sup>24</sup>      | 15        | Ocular fix to periost with SO tendon frag and SO tenectomy and LR rec and MR res | 64 <sup>Δ</sup>          | 3.9 <sup>Δ</sup> | Limited abd<br>No change of add, dep, elev              | 11 (73)                         | 4 (27)               | 0                  | —  | 11 (73)                  | None   | 19                   |
| Velez et al <sup>25,c</sup>      | 3         | LR fix to periost and SO tenotomy  | 41 <sup>Δ</sup>          | 7.3 <sup>Δ</sup> | Limited abd (mean, -3.2)<br>No change of add, dep, elev | 3 (100)                         | 0 (0)                | 0                  | —  | 3 (100)                  | Eyelid swelling  | 12.7                 |
| Srivastava et al <sup>13</sup>   | 5         | Globe fix to medial palpebral lig using suture and LR rec                        | 69 <sup>Δ</sup>          | —                | Limited abd<br>No change of add, dep, elev              | 1 (20)                          | 4 (80)               | 0                  | —  | 1 (20)                   | Mild fullness, congestion over MR                            | 7                    |
| Sharma et al <sup>12</sup>       | 4         | Ocular fix to periost with suture and LR rec                                     | 81 <sup>Δ</sup>          | 8 <sup>Δ</sup>   | —   | 4 (100)                         | 0                    | 0                  | —  | 4 (100)                  | Hyperemia on medial canthal area                             | 10                   |
| Salazar-Leon et al <sup>10</sup> | 5         | Globe fix using fascia lata and LR rec and MR dissec                             | 57 <sup>Δ</sup>          | 6 <sup>Δ</sup>   | Limited abd<br>No change of add, dep, elev              | 2 (40)                          | 3 (60)               | 0                  | —  | 2 (40)                   | None   | 22.5                 |
| Saunders et al <sup>26</sup>     | 3         | Ant trans of SO tendon and LR rec and/or MR res                                  | 32 <sup>Δ</sup>          | 0 <sup>Δ</sup>   | No change abd, add, dep, elev                           | 1 (33)                          | 1 (33)               | 1 (34)             | Marg myotomy of LR and MR re-res and SO tenotomy (2) | 2 (66)                   | Hypertropia (mean, 13 <sup>Δ</sup> )<br>Paradoxal ocular mov | —                    |
| Maruo et al <sup>7,d</sup>       | 49        | Ant trans of SO tendon and MR res and/or LR rec                                  | 16 <sup>Δ</sup>          | —                | —   | 36 (78)                         | 10 (22)              | 0                  | —  | 36 (78)                  | None   | 1-48                 |

|                           |   |  |                   |                  |                               |        |                   |   |          |      |    |
|---------------------------|---|--|-------------------|------------------|-------------------------------|--------|-------------------|---|----------|------|----|
| Young et al <sup>27</sup> | 8 | Ant trans of SO tendon and LR rec or plication | 48.6 <sup>a</sup> | 9.4 <sup>a</sup> | No change add, abd, dep, elev | 6 (75) | 1 (12.5) 1 (12.5) | — | 6 (75)   | None | 24 |
| Metz et al <sup>28</sup>  | 1 | Ant trans of SO tendon and LR rec              | 70 <sup>a</sup>   | 10 <sup>a</sup>  | Limited abd, 5°-8° add        | 1      | 0                 | 0 | 1 (100%) | None | 7  |

*Abd*, abduction; *Add*, adduction; *Comp*, complications; *Dep*, depression; *Elev*, elevation; *Eso*, esotropia; *Exo*, exotropia; *Fix*, fixation; *IR*, inferior rectus muscle; *LR*, lateral rectus muscle; *Marg*, marginal; *Mov*, movement; *MR*, medial rectus muscle; *Resid*, residual; *Sec*, secondary; *Rec*, recession; *Res*, resection; *SO*, superior oblique muscle; *Trans*, transposition.

<sup>a</sup>Success defined as an ocular deviation within 10° of orthotropia in primary position.

<sup>b</sup>After secondary operation, Taylor et al observed that the paretic eye had satisfactory ocular alignment with good adduction but little or no abduction.

<sup>c</sup>Veletz et al reported a retrospective analysis of 7 consecutive patients who underwent rectus muscle inactivation by orbital wall fixation; 3 had complete oculomotor nerve palsy; 1 patient underwent LR recess and MR res; 1 patient underwent LR rec and vertical rectus trans previously.

<sup>d</sup>Maruo et al reported 138 cases of paralytic exotropia due to oculomotor palsy; 49 had complete oculomotor nerve palsy.

no improvement in ocular motility, which is expected with this procedure.

Compared to Kauffmann's procedures,<sup>15</sup> our procedure has the advantage of avoiding the risk of orbital hemorrhage (damage of vortex veins) and globe perforation. The superolateral vortex vein is only a few millimeters posterior to the medial insertion of the superior oblique tendon and is very close to the lateral edge of the superior rectus muscle.<sup>30</sup> The surgeon paid particular attention to avoiding the vortex vein during the procedure, and we did not observe any complications that indicated unusual vortex vein pressure in the patients who participated in the long-term follow up. We recognize that medial transpositions of the lateral rectus muscle have been reported to result in retinal detachments due to increased choroidal vortex venous pressure; however, in our technique the new positions of the arms of the lateral rectus muscle do not increase choroidal vortex venous pressure because neither the new positions nor the new attachments intersect the vortex veins. We found no evidence of this complication during the course of follow-up.

No clinical signs of optic nerve compression, including visual field defects, loss of visual acuity, relative afferent pupillary defect, and loss of color vision<sup>31</sup> were observed in any patient. In our technique the positions of the arms of the lateral rectus do not intersect with the optic nerve. The medial, posterior edge of the superior oblique tendon is approximately 17–19 mm (mean, 18.8 mm) posterior to the limbus and as much as 14 mm (mean, 13.6 mm) posterior to the medial insertion of the superior rectus tendon. This edge of the tendon is approximately 8 mm superior to the posterior pole of the globe. The center of the optic disc is approximately 4 mm medial and 0.8–1 mm superior to the foveola.<sup>30</sup> The optic nerve pierces the sclera approximately 3 mm nasal and 1 mm inferior to the posterior pole. The center of the optic disc was 27 mm from the nasal limbus and 31 mm from the temporal limbus.<sup>30</sup> The width of the lateral rectus muscle-tendon has been reported as 9.6 mm (7.0–12.0 mm).<sup>32</sup> The width of half of the lateral rectus muscle was approximately 5 mm. There is a distance of >5 mm between the posterior end of the superior oblique muscle and the optic nerve sheaths.<sup>30</sup> The explanation for this may be that this technique is not the cause of compression on the optic nerve sheaths.

Because only one extraocular muscle was disinserted from the sclera, there is no probability of anterior segment ischemia in our technique. In 5 of the 10 cases, we obtained a successful outcome with a one-muscle operation, which is a better rate of success than generally obtainable using techniques that require involvement of more muscles. In addition, our technique allows a subsequent superior oblique procedure if more adduction is required.

Two patients had a fibrotic lateral rectus muscle. Because of the shortness of fibrotic muscles, it is impossible to reattach them to the medial rectus area. However, by using the hang-back technique, we could reinsert the muscle. Thus these cases had undercorrection rather than



overcorrection. Our procedure seems to provide the perfect correction with intraoperative Hirshberg testing, but it did not provide enough postoperative correction.

Diplopia in patients with oculomotor nerve palsy is not common on presentation, but diplopia may become seriously debilitating following ptosis repair.<sup>24</sup> We expected postoperative diplopia at least in 1 gaze direction in patients who had preoperative binocularity with prisms and good visual acuity in both eyes. In our series, 2 patients had complete resolution of their diplopia in the primary position after surgery, and 2 patients who had pre-palsy binocularity achieved limited binocularity in the primary position and a very limited range of gaze with prism correction.

Although our study is limited by the lack of controls, the modified Kaufmann's procedure presented here overcomes some of the limitations of previous procedures. It does not, for example, require complicated calculations or introduce any foreign tissues or materials into the orbit. It has not been associated with significant complications. Moreover, the procedure can be performed on children and results in orthotropia in the primary position via a one-muscle operation with, in many cases, stable long-term results.

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